Joint Beginning and Intermediate Engineering Graphics
2nd Week 1st Meeting Lecture Notes
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Topic: Geometric Construction

1st Subject: 2D Geometric Shape Construction and Division

1A. Definitions of some common shapes:

Square: a quadrilateral shape with four sides with equal length and four 90º angles (equiangular and equilateral).
Triangles: three-sided polygons. They can be in any of the following three categories:

1. **Equilateral triangle:** one with three equal sides and three 60º angles (equiangular and equilateral).
2. **Isosceles triangle:** one with two equal sides and two equal angles.
3. **Right triangle:** one with a right angle (90-degrees).

Rectangle: a four-sided parallelogram with two pairs of parallel opposite sides and four 90º right angles (equiangular).
Parallelogram: a quadrilateral with two pairs of parallel opposite sides
Rhombus: a quadrilateral with four equal sides and two pairs of equal opposite angles.
Trapezoid: a quadrilateral with exactly one pair of parallel sides.
Circle: a plane curve everywhere equidistant from a given fixed point called the center.
Ellipse: a circular shape with one major axis (or major diameter, or major radius) and one minor axis (or minor diameter, or minor radius). A circle seen at an angle appears to be an ellipse.
Hypotenuse: the side of a right triangle opposite the right angle. In a right triangle,
The square of the hypotenuse = the square of one side + the square of the other side.
The hypotenuse = the root of the sum of the square of one side + the square of the other side.
Altitude: the perpendicular distance from the base of a geometric figure to the opposite vertex, parallel side or parallel surface (or simply the height).

1B. Relationships between the above common shapes:

Square, Rectangle, Parallelogram, and Rhombus all have four sides and belong to the group of **"quadrilateral shapes"** (the word quadrilateral literally means "four-sided"). Their main differences are in their angles and length of sides, as illustrated by the table below:

Name of Shapes	Angles	Lengths of Sides
Square	four right angles (equiangular)	four equal sides (equilateral)
Rectangle	four right angles (equiangular)	two sets of equal sides
Parallelogram	two sets of equal angles (one acute, one obtuse)	two sets of equal sides
Rhombus	two sets of equal angles (one acute, one obtuse)	four equal sides (equilateral)

Triangles are "indestructible": if the length of the three sides of any given triangle remain the same, then the shape of that triangle can NOT be changed.

Triangulation: irregular polygons can be drawn after being visually divided into a collection of triangles; these triangles are drawn to help generate the irregular polygons.

2. Sketching Tips:

Pay attention to proportion: sketch lightly first, check proportions, make corrections, going over the lines. Sketch a light grid background first. Use pencil held at arm's length to measure the length of object.

3. Basic Geometric Construction:

Circles: a circle has circumference, radius and diameter. To draw a circle: find the center by drawing two perpendicular lines, set the legs of the compass so that the distance between them is equal to the radius of the circle, place the point of the compass on the center of the circle, swing that other leg to draw the circle.

To sketch circles: use the "four centerlines method", sketch two perpendicular centerlines to find the center at crossing point, sketch another set of perpendicular centerlines through the center and at an angle of 45 degree to the first set, mark off eight points along the centerlines equally spaced from the center point, sketch a light curve through the eight points, check for accuracy and smoothness, make correction if needed, then darken in the circle.

To sketch ellipses: use the "two centerlines method", sketch two perpendicular centerlines, place four marks along the centerlines to indicate major and minor axis, sketch a light curve through the four points, check for accuracy and smoothness, make correction if needed, then darken in the ellipse.

To draw an arc: an arc is a segment of the circumference of a circle, a chord is the distance between the endpoints of an arc. To draw an arc, use same method as circle, but you need chord length or angle.

To bisect (divide into two equal parts) a line: swing two arcs with radius greater than half the length of the line and the centers at the two endpoints, draw a line connecting the two crossing points of the arcs.

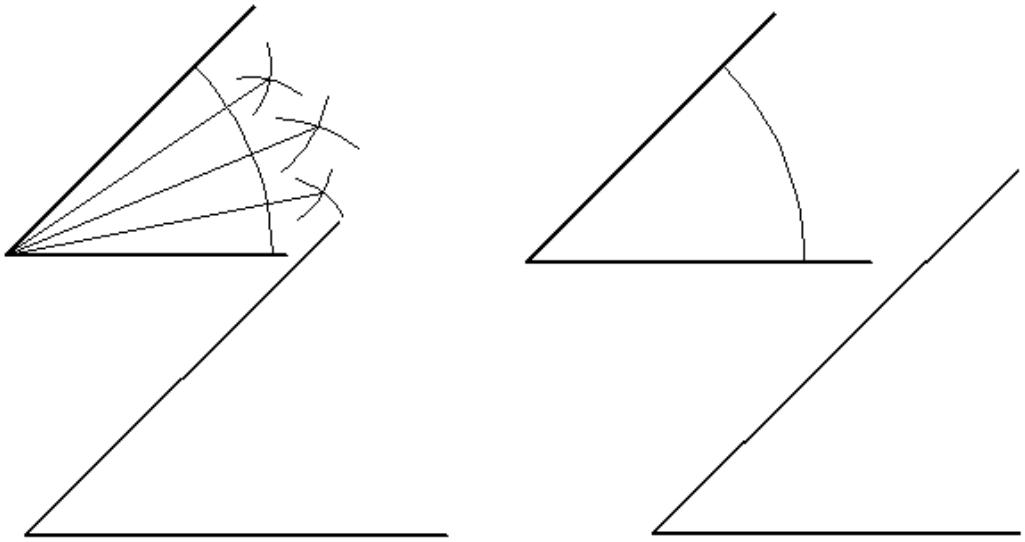
To bisect an arc: same method as bisecting a line.

To bisect an angle: swing an arc with the vertex of the angle as the center to cross the two sides forming the angle and get two crossing points, swing two arcs with the crossing points as centers and with a radius greater than one-half of the distance between the crossing points to get a crossing point in the middle, which will be connected to the vertex to bisect the angle.

To divide a line into any number of equal parts: draw a "dividing line" forming any angle with the line to be divided, mark off any number of equal parts on the "dividing line", connect the last mark-off point on the "dividing line" to the line to be divided with a "connecting line", then draw parallel "connecting lines" through all other mark-off points on the "dividing line" to divide the line.

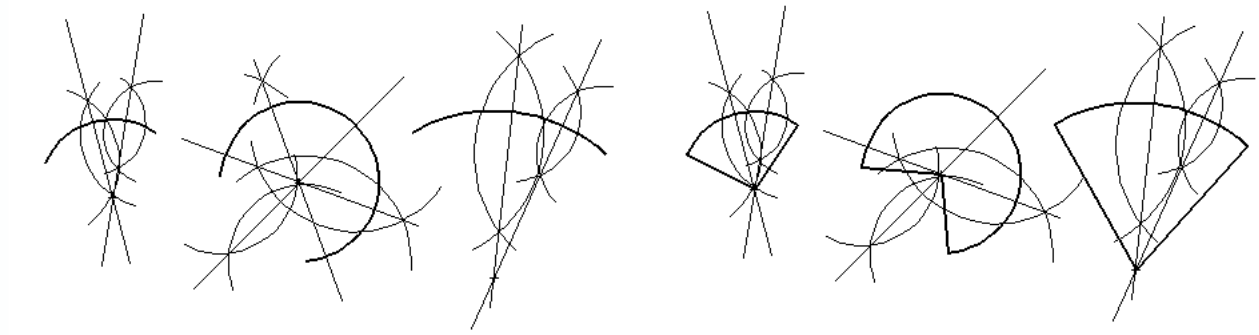
To construct an equilateral triangle: draw the base line, using the length as a radius to swing two crossing arcs with the endpoints of the base line as centers, connect the crossing point to the two endpoints of the base line.

To draw a square when the diagonal is known: draw a circle with the length of the diagonal as the diameter, draw perpendicular lines through the center of the circle, connect the points where the perpendicular lines cross the circumference of the circle.
To draw a square when the sides are known: draw one side, draw two crossing diagonal lines forming 45 degree angles with the two endpoints of the side line, swing arcs with the length of the side line as radius and endpoints of the side line as centers, connect the crossing points and endpoints to get a square.
How to draw hexagon, the Star of David? See page 26 of the "Blue Book" or Handouts
To divide an angle into equal parts (more than 2 parts):
1. If the number of parts=2^n (2x2x2x2…, or 2, 4, 8, 16, 32, …): Use the compass to swing one arc with the vertex as the center; this gives two crossing points. Use the two crossing points as centers to swing two new arcs with a radius greater than half the distance between the centers; the two new arcs generate two new crossing points; connect them to the vertex of the angle to bisect it. Use the same method to continue bisecting the angle.
2. If the number of parts is any integer other than 2^n, than use the protractor: measure the angle; calculate the angle of one equal part (dividing the angle by the number of parts); then mark off the parts using protractor and divider. Extension of the lines and/or construction of an arc might be needed.



To divide an arc into equal parts:
1. If the number of parts=2^n (2x2x2x2…, or 2, 4, 8, 16, 32, …): Use the compass to swing two arcs with the endpoints of the arc to be divided as the center; this gives two crossing points. Connect the two crossing points to bisect the arc. Use the same method to continue bisecting the angle.
2. If the number of parts is any integer other than 2^n, than locate the center of the arc first by bisecting the arc, then bisect one segment of the arc again, the two bisecting lines will cross each other to generate the center of the arc. Then from the center of the arc,

draw two lines to connect to the endpoints of the arc. This gives an angle to be divided into any equal parts. Then use the protractor and divider to divide the angle and the arc.



Practice drawing angles and arcs (angle=60°, 90°, 120°, and 160°) and using protractor to divide them into five equal parts:

2nd Subject: 3D Solid Identification

1. Definitions:

- **Polyhedra:** solids bounded by plane surfaces called **faces** with lines of intersection of faces called **edges**. Convex solids whose faces are all congruent regular polygons are **regular polyhedra**, also called **Platonic solids**, including **tetrahedron** (4 triangles), **cube**, **octohedron** (8 triangles), **dodecahedron** (12 triangles), and **icosahedron** (20 triangles).
- **Solid of revolution:** a solid generated by revolving a plane figure about an axis in the plane of the figure.
- **Solids bounded by warped surfaces:** these types of solids have no group name. Example: screw thread.

Note: in practice, the term solid refers to any 3D closed form, which may be either solid or hollow.

2. Basic 3D solids:

- **Cylinder:** a solid bounded by two parallel circular planes. It can be either right cylinder or oblique cylinder.
- **Cone:** a solid with a circular base, a vertex at the end of a straight line moving along the circumference of the circular base. It can be either right cone or oblique cone.
- **Cube:** a regular solid having six congruent square faces.

3rd Subject: Angles and Inclination, Perpendicularity and Parallelism

1. Types of angles: Right angle (90°), obtuse angle (>90°) and acute angles (<90°):

2. Perpendicular lines (intersecting at 90º angle) and parallel lines (same plane, non-intersecting).

Study Questions

1. What are the definitions for right, obtuse, and acute angles?

2. Write down the definitions for the following and make a sketch for each of them: square, equilateral triangle, isosceles triangle, rectangle, parallelogram, rombus, cylinder,
cone, cube, circle, and ellipse

3. What does the word hypotenuse mean?
4. What does the word altitude mean?
5. Practice the following basic geometric construction with freehand sketching and with drawing by using tools: circles, ellipses, arc, equilateral triangle, square when the length of the diagonal is known, square when the length of the sides are known.